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Brandon YIP et al.

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Title: Coated Sunglass Lens

Group Art Unit: 2873

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SUBMISSION OF CERTIFIED COPY OF PRIORITY DOCUMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The benefit of the filing date of the following priority foreign application(s) in the following foreign country is hereby requested, and the right of priority provided in 35 U.S.C. § 119 is hereby claimed.

Country: Australia

Patent Application No(s).: PP8997

Filed: March 4, 1999

In support of this claim, enclosed is a certified copy(ies) of said foreign application(s). Said prior foreign application(s) is referred to in the oath or declaration. Acknowledgment of receipt of the certified copy(ies) is requested.

Respectfully submitted,

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Patent Office
Canberra

I, KIM MARSHALL, MANAGER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PP 8997 for a patent by SOLA INTERNATIONAL HOLDINGS LTD filed on 04 March 1999.

WITNESS my hand this
Twenty-fifth day of August 1999

KIM MARSHALL
MANAGER EXAMINATION SUPPORT
AND SALES

P/00/009
Regulation 3.2

AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Invention Title: **Coated sunglass lens (2)**

The invention is described in the following statement:

COATED SUNGLASS LENS (2)

The present invention relates to optical articles bearing a light absorbing coating.

The optical articles according to the present invention are preferably employed in the preparation of articles such as optical lenses, including spectacle lenses, including sunglass lenses, visors, shields, glass sheets, protective screens, and the like.

Sunglasses generally serve to attenuate transmitted light, but aside from the level of light transmittance, there are other features that distinguish different sunglass lenses, such as material, transmitted colour, scratch resistance, reduction of side glare, ultra-violet transmittance, cosmetic appearance etc. Coatings may be applied to enhance the performance of sunglass lenses. Such coatings might include scratch resistant coatings, hydrophobic coatings for easier cleaning, anti-reflection coatings on the concave surface for reducing side glare or "mirror" (or "interference") coatings for producing fashionable lens colours. General purpose sunglass lenses should meet certain standard specifications, including luminous transmittance, traffic signal recognition and UV transmittance (e.g. ANSI Z80.1-1995).

In addition to their performance characteristics, sunglass lenses should be simple and economical to produce in a reliable manner.

As is known in the prior art, the preferred method for producing sunglass lenses is dependent on the material involved. In all cases a light-attenuating material is either incorporated into the substrate material or applied over its surface in a process known as "tinting". For example, glass lenses are often tinted by introducing coloured additives to the molten glass, and similarly polycarbonate lenses are injection-moulded from pre-coloured plastic granules. A disadvantage associated with this method of production is that for economical reasons, very large batches of coloured raw material must be purchased, limiting flexibility in the range of tint colours that can be offered in the sunglass lens product. Moreover,

prescription sunglass lenses with highly varying thickness will also exhibit non-uniform transmittance when coloured in this way. Hard resin lenses (another commonly used ophthalmic plastic) are usually dipped in a hot, liquid dye which is imbibed into the plastic. This process also has disadvantages, such as difficulty in achieving tint uniformity, poor colour reproducibility and its requirement that if the lens has a scratch resistant coating, it must be semi-permeable to allow imbibation of the dye molecules, hence compromising the scratch resistance. If a reflective mirror coating is desired, the tinted substrate is then cleaned and coated in an evaporative vacuum deposition process. Such multi-stage processes are both time-consuming and expensive.

One proposal in the prior art to overcome some of the problems associated with lens tinting is to apply the light absorbing material as a thin film on an essentially transparent substrate. United States Patent No. 5,770,259 (Parker and Soane) describes a method for tinting sunglass lenses using a curable primer containing a tinting agent. Vacuum deposition allows the light absorbing coating to be applied in a relatively fast, clean, flexible and controllable manner. United States Patent No. 5,729,323 (Arden and Cumbo) describes a sunglass formed by depositing a multi-layer light absorbing coating containing TiO_x (x=0.2-1.5) on the concave surface of the substrate. The coating is anti-reflective from the wearer's side of the lens. United States Patent No. 3679291 (Apfel and Gelber) describes a metal-dielectric multi-layer coating that is light absorbing and has an asymmetric reflectance, being anti-reflective from one side and with strong colour on the other side.

Another time-consuming step in the production of corrective sunglass lenses is the surfacing of the lenses. Corrective (or prescription) sunglass lenses are often dispensed using "semi-finished blanks" - lenses that have a pre-moulded front surface and a back surface that must be ground and polished to satisfy the individual wearer's corrective prescription. For plastic lenses in particular, tinting and the deposition of further lens coatings must be performed after surfacing the lens, resulting in a long and labour-intensive process to produce and deliver the prescription sunglass lenses. One means to simplify and accelerate lens delivery

is to employ a wafer lamination scheme, where front and back lens wafers spanning a large range of optical powers are simply glued together to produce a lens of almost any desired prescription. Instead of maintaining a complex optical grinding and polishing workshop, the optical dispenser need only maintain an inventory of wafers and a lamination unit. The use of fast curing glues allows lenses to be produced in only minutes. Additional performance enhancing coatings may be applied to the wafers at the factory, so that the dispenser may provide the desired product features immediately, simply by selecting the appropriate wafers from his inventory.

For laminated lens wafer systems, for example of the Sola International Matrix®-type, liquid bath tinting is not a desired option - it is a low yield process involving significant handling and possible distortion of fragile wafers. Such tinted lenses may also exhibit poor abrasion and scratch resistance and variable depth of colour.

Accordingly, it is an object of the present invention to overcome, or at least alleviate, one or more of the difficulties or deficiencies related to the prior art.

Accordingly, in a first aspect of the present invention there is provided an optical lens including

a lens element; and

a light absorbing coating on the front surface of the lens that

attenuates transmitted light;

has a coloured or colourless reflection as seen from the front of the lens; and

is anti-reflective as seen from the eye side of the lens.

In a further aspect of the present invention there is provided an optical lens including

a lens element; and

a light absorbing coating on the rear surface of the lens, such that the light absorbing coating

attenuates transmitted light;

has a coloured or colourless reflection as seen from the front of the lens; and

is anti-reflective as seen from the eye side of the lens.

The optical lens is preferably a sunglass lens. The lens element may be a sunglass lens, ophthalmic lens element, visor or the like. An ophthalmic lens element is preferred.

By the term "ophthalmic lens element", as used herein, we mean all forms of individual refractive optical bodies employed in the ophthalmic arts, including, but not limited to, lenses, lens wafers and semi-finished lens blanks requiring further finishing to a particular patient's prescription.

Where the lens element is an ophthalmic lens, the ophthalmic lenses may be formed from a variety of different lens materials, including glass and particularly from a number of different polymeric plastic resins. A common ophthalmic lens material is diethylene glycol bis (allyl carbonate), commonly referred to as CR39 (PPG Industries). Lens materials with higher refractive indices based on acrylic or allylic versions of bisphenols or allyl phthalates and the like are also growing in popularity. Other examples of lens materials that may be suitable for use with the invention include other acrylics, other allylics, styrenics, polycarbonates, vinylics, polyesters, sulphur-containing polymers and the like.

It will be understood that, in accordance with the present invention, one or more surfaces of a lens element is coated with a light absorbing coating. The light absorbing coating may preferably serve three purposes at once - to attenuate transmitted light, effectively providing the sunglass "tint," to produce a coloured or colourless reflection that is of pleasing appearance as seen from the front of the lens and to reduce or minimise back reflections seen by a wearer of the sunglass lenses.

By the term "coloured or colourless reflection", as used herein, we mean that light from a white source is reflected from the surface of the lens element to an observer such that the reflected light is coloured or white respectively.

In a preferred form, the reflection from the front of the lens element is either coloured or colourless and bright, in which case the light absorbing coating may be said to function as a mirror coating. Thus, the tinting and mirror coating processes may be combined into one with this coating.

Since the light absorbing coating renders the lens anti-reflective when viewed from one side of the coating and exhibits a selected colour or colourless reflection when viewed from the other side, we may describe the coating as displaying an "asymmetric reflectance".

The light absorbing coating with asymmetric reflectance may be constructed of a plurality of overlapping light absorbing and generally transparent layers, and wherein the thickness and/or number of the respective layers are selected to provide an anti-reflective effect on the eye side of the optical lens and a desired colour on the other side of the lens.

The number and/or thickness of the light absorbing and generally transparent layers may be selected to provide an eye side anti-reflective coating utilising suitable computer software.

The combination of light absorbing and generally transparent layers may be selected to provide a bright or coloured reflection when viewed from the front of the lens at the same time. A mirror type effect may be produced.

The transparent layers may be formed from any suitable optical material. The transparent layers may be formed of a dielectric material. Preferably the dielectric layers may be formed from metal oxides, fluorides or nitrides. Metal oxides which may be used for forming transparent layers include one or more of Al_2O_3, $BaTiO_3$, Bi_2O_3, B_2O_3, CeO_2, Cr_2O_3, Ga_2O_3, GeO_2, Fe_2O_3, HfO_2, In_2O_3, Indium-tin oxide, La_2O_3, MgO, Nd_2O_3, Nb_2O_5, Pr_2O_3, Praseodymium-titanium oxide, Sb_2O_3, Sc_2O_3, SiO, SiO_2, SnO_2, Ta_2O_5, TiO, TiO_2, Ti_2O_3, Ti_3O_5, WO_3, Y_2O_3, Yb_2O_3, ZnO, ZrO_2. Fluorides which may be used include one or more of AlF_3, BaF_2, CaF_2, CdF_2, CeF_3, HfF_4, LaF_3, LiF, MgF_2, NaF, Na_3AlF_6, $Na_5Al_3Fl_{14}$, NdF_3, PbF_2, PrF_3, SrF_2, ThF_4, ZrF_4. Suitable nitrides include Si_3N_4 and AlN. Carbon,

particularly diamond-like carbon may be used.

A silica (SiO_2) material is preferred.

In a particularly preferred embodiment, the first deposited layer may be a silica layer followed by alternating light absorbing and generally transparent, preferably silica, layers. The transparent dielectric layers may be substantially thicker than the light absorbing or metallic layers. The first layer may be of approximately 10 to 75 nm, preferably approximately 25 to 60 nm. This first layer may provide significant improvement in the abrasion resistance of the multi-layer coating.

The generally transparent layers within the body of the light absorbing coating may be relatively thick. The thicknesses may be such as to generate interference effects which substantially cancel out internal reflections. Thicknesses of for example from approximately 20 nm to 100 nm, preferably approximately 25 nm to 85 nm may be used.

The light absorbing layers of the light absorbing coating may be formed from any suitable material. Metals, semiconductors, metal oxides or nitrides may be used. Metals may be selected from one or more of Silver (Ag), Aluminium (Al), Gold (Au), Barium (Ba), Boron (B), Cadmium (Cd), Cerium (Ce), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Germanium (Ge), Hafnium (Hf), Indium (In), Iridium (Ir), Potassium (K), Lanthanum (La), Magnesium (Mg), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Neodymium (Nd), Niobium (Nb), Lead (Pb), Palladium (Pd), Platinum (Pt), Rhenium (Re), Antimony (Sb), Selenium (Se), Silicon (Si), Tin (Sn), Strontium (Sr), Tantalum (Ta), Titanium (Ti), Tellurium (Te), Thallium (Tl), Vanadium (V), Tungsten (W), Zinc (Zn), Zirconium (Zr) or mixtures thereof.

A metallic layer may be selected to provide a generally neutral, e.g. greyish transmission. Accordingly a silver-coloured metal, e.g. Aluminium (Al), Chromium (Cr), Indium (In), Nickel (Ni), Niobium (Nb), Palladium (Pd), Tin (Sn), Tantalum (Ta), Titanium (Ti), Tungsten (W), Zinc (Zn), or Zirconium (Zr) or

mixtures thereof may be used.

Alternatively, a coloured metal or semiconductor, e.g. Gold (Au), Copper (Cu) or Silicon (Si) may be used to provide a coloured transmission.

The thickness of the light absorbing layers is such as to attenuate transmitted light. The light absorbing layers may generally be of a substantially reduced thickness relative to the transparent or dielectric layers. For example if the material used is Niobium, the light absorbing layers may be from approximately 1 nm to 10 nm, preferably approximately 2 nm to 5 nm in thickness.

In a preferred form, the light absorbing coating may include a total of 4 to 12 alternating light absorbing and generally transparent layers, preferably 6 to 8 alternating layers. An additional primer layer may be included, as discussed above.

The resultant coating may exhibit a silver (colourless) mirror-type appearance. Alternatively the light absorbing coating may be modified to produce a different colour coating. A combination of dielectric top coatings may be applied to obtain a desired colour of reflectance. A silica top coat may be added to modify colour and additionally enhance abrasion resistance.

Accordingly in a preferred form, the light absorbing coating includes alternating layers of a dielectric material and a metallic material.

More preferably the light absorbing coating includes alternating layers of silica (SiO_2) and chromium metal. A generally neutral (but slightly brown) transmission results.

In a still further preferred form, the light absorbing coating includes an additional titanium dioxide layer or layers of such a thickness to provide a desired colour to the optical lens.

Alternatively, the light absorbing coating includes alternating layers of

silica and niobium metal. A very neutral grey transmission results.

Preferably the light absorbing coating includes an additional niobium oxide (Nb_2O_5) and/or silica (SiO_2) layer of such thicknesses to provide a desired colour to the optical lens.

In a further alternative, the light absorbing coating includes alternating layers of silica and zirconium metal. This combination is preferred where a grey transmission is required.

In a still further preferred embodiment the light absorbing coating further includes compatible dielectric layers of suitable thickness to provide a desired colour to the optical lens.

The optical lens may further include one or more additional coatings.

Accordingly in a further aspect of the present invention there is provided a multi-coated optical lens including

an optical article; and

a light-absorbing coating deposited on at least one surface of the optical article; the light-absorbing coating including a plurality of overlapping light absorbing and generally transparent layers, and wherein the thickness and/or number of the respective layers being selected to provide an anti-reflective effect on the eye side of the optical lens and a desired colour on the other side of the optical lens, and

a secondary coating which provides a desirable optical and/or mechanical and/or chemical property to the optical article.

The multi-coated optical lens may preferably be a sunglass lens.

The secondary coating may preferably underlay or overlay the light absorbing coating.

The secondary coating may be of any suitable type. The secondary

coating may be one or more of an anti-reflective, abrasion resistant, hydrophobic or impact-resistant coating. An abrasion-resistant coating is preferred. The combination of an abrasion resistant coating and an anti-reflective coating is particularly preferred.

An abrasion-resistant (hard) coating including an organosilicone resin is preferred. A typical organosilicone resin that is suitable for use in the present invention has a composition comprising one or more of the following:

1) organosilane compounds with functional and/or non-functional groups such as glycidoxypropyl trimethoxy silane;
2) co-reactants for functional groups of functional organosilanes, such as organic epoxies, amines, organic acids, organic anhydrides, imines, amides, ketamines, acrylics, and isocyanates; colloidal silica, sols and/or metal and non-metal oxide sols; catalysts for silanol condensation, such as dibutylin dilaurate;
3) solvents such as water, alcohols, and ketones;
4) other additives, such as fillers.

Abrasion resistant coats of acrylic, urethane, melamine, and the like may also be used. These materials, however, frequently do not have the good abrasion resistant properties of organo-silicone hard coatings.

The abrasion-resistant (hard) coating may be coated by conventional methods such as dip coating, spray coating, spin coating, flow coating and the like or by newer methods such as Plasma Enhanced Chemical Vapour Deposition. Coating thicknesses of between approximately 0.5 and 10 microns are preferred for abrasion and other properties.

The secondary abrasion resistant coating may be applied to the front and/or rear lens surfaces. The abrasion resistant coating may be of the type described in United States Patent 4,954,591 to the Applicants, the entire disclosure of which is incorporated herein by reference.

In a preferred aspect, one or both surfaces of the optical article may be

subjected to a surface treatment to improve bondability and/or compatibility of the light absorbing and/or secondary coating. The surface treatment may be selected from one or more of the group consisting of plasma discharge, corona discharge, glow discharge, ionising radiation, UV radiation, flame treatment and laser, preferably excimer laser treatment. A plasma discharge treatment is preferred. The surface treatment, alternatively or in addition, may include incorporating another bonding layer, for example a layer including a metal or metal compound selected from the group consisting of one or more of Chromium, Nickel, Tin, Palladium, Silicon, and/or oxides thereof.

The optical article may be a sunglass lens of the wrap-around or visor type, for example of the type described in International Patent Application PCT/AU97/00188 "Improved Single Vision Lens" to Applicants, the entire disclosure of which is incorporated herein by reference.

In a further aspect of the present invention, there is provided a method for preparing an optical lens, which method includes

providing

a lens element; and

a light absorbing coating on the front surface of the lens that

attenuates transmitted light;

has a coloured or colourless reflection as seen from the front of the lens; and

is anti-reflective as seen from the eye side of the lens; and

depositing the light absorbing coating on a surface of the optical lens element.

According to the present invention it has been found that, following the method mentioned above, it is possible to achieve a relatively thin, light absorbing coating with consequent advantages in both optical and mechanical properties.

Preferably the method further includes

providing

a lens element,

a light absorbing material, and

a generally transparent material;

depositing overlapping layers of light absorbing material and generally transparent material on a surface of the optical lens element, the number and/or thickness of the respective layers being selected to provide a desired colour to the front surface of the optical lens and an anti-reflective effect on the eye side of the optical lens.

In a preferred aspect the light absorbing materials are metallic materials and the generally transparent materials are dielectric materials. More preferably Nb and SiO_2, Zr and SiO_2 or Cr and SiO_2, are deposited as alternating layers.

The deposition step may be a vacuum deposition step. The deposition step may be conducted in a coating apparatus. A box coater or sputter coater may be used.

The light absorbing coating may preferably be formed on the surfaces of the substrate according to the process and the box coaters as described in the Italian Patent No. 1.244.374 the entire disclosure of which is incorporated herein by reference.

In accordance with said method, the various layers of the light absorbing coating may be deposited in subsequent steps utilising a vacuum evaporation technique and exposing the growing layers to a bombardment of a beam of ions of inert gas.

Moreover, in accordance with the preferred method, the deposition of the layers may be achieved at a low temperature (generally below 80°C), using an ion beam having a medium intensity (meaning the average number of ions that reach the substrate) included between approximately 30 and 100 μA/cm2 and the energy included between approximately 50 and 100 eV.

Preferably, the optical article is maintained at an elevated temperature during the deposition of the various layers of the light absorbing coating.

More preferably the lens element includes

a front lens wafer including

a contact surface,

a complementary back lens wafer, including

a contact surface

and the overlapping layers of light absorbing material and generally transparent material are deposited on a surface of the front and/or complementary back lens wafer.

A laminate adhesive may be applied to one or both contact surfaces, the front lens wafer and back lens wafer being brought into contact and the laminate so formed being subjected to a curing step to form a laminate optical lens.

In a further preferred aspect of the present invention, there is provided an optical lens element including

a lens wafer having

a first lens surface; and

a second lens surface,

the first or second surface having deposited thereon

a light absorbing coating that

attenuates transmitted light;

has a coloured or colourless reflection as seen from the front of the sunglass lens; and

is anti-reflective as seen from the eye side of the lens.

The laminate optical lens may be a sunglass lens.

Preferably the light absorbing coating is an asymmetric reflectance, light absorbing coating including a plurality of overlapping light absorbing and generally transparent layers; the thickness and/or number of the respective layers being selected to provide a desired colour to the optical lens element and an anti-reflective effect on the eye side of the lens element after lamination of the lens wafer.

The coated lens wafer may be a front surface wafer or a rear surface wafer. Where the coated lens wafer is a front surface wafer the light absorbing coating may be deposited on the first (front) or second (rear) lens surface thereof.

Where the coated lens wafer is a rear surface wafer, the light absorbing coating is preferably deposited on the first (front) surface thereof.

Accordingly in a still further aspect of the present invention, there is provided a laminate optical lens including

a front lens wafer including

a contact surface;

a complementary back lens wafer including

a contact surface; and

a light absorbing coating deposited on a contact surface, which light absorbing coating

attenuates transmitted light;

has a coloured or colourless reflection as seen from the front of the sunglass lens; and

is anti-reflective as seen from the eye side of the lens.

Preferably the light absorbing coating includes a plurality of overlapping light absorbing and generally transparent layers; the thickness and/or number of the respective layers being selected to provide a desired colour to the laminate optical lens and an anti-reflective effect on the eye side of the laminate optical lens, as discussed above.

It will be understood that, in this embodiment, in addition to the advantages of the present invention described above, the light absorbing coating provided may be protected by the optical lens wafers themselves and is thus virtually indestructible.

In addition, abrasion resistant and like coatings of the type described above may be applied to the external surfaces of the laminate optical article.

The laminate optical article may be fabricated in a manner similar to that described in International Patent Application PCT/AU96/00805, "Laminate Article", to Applicants, the entire disclosure of which is incorporated herein by reference.

Where the light absorbing coating is applied inside the laminate, particularly for hard resin lenses, because the lens is not tinted in a liquid bath, the scratch resistant coating applied to the exterior of the wafers does not need to be semi-permeable (to allow passage of the tint molecules through to the substrate). Therefore, the most durable, non-tintable scratch resistant coatings may be applied and the final product is extremely durable. The light absorbing coating is protected inside the laminate and cannot be scratched. Because the light absorbing coating is located approximately in the centre of the laminate, when the lens is edged for mounting into spectacle frames, the edges appear “dark” and it is difficult to discern that the “tinted” appearance of the lens is due only to a very thin coating. Finally, as can be seen in Figure 2 below, there is a double reflection from the front of the lens, one “white” reflection from the front of the front wafer and one coloured reflection from the light absorbing coating inside the laminate. If the front wafer is thin and has no optical power, the two reflections overlay one another and only a single reflection is observed. However, if the front wafer is thick and has surfaces of different curvature, then the two front reflections become apparent. A quite pleasing “glossy” effect is obtained.

Before the lens wafers of the laminate lens are bonded, they may be too thin to meet United States F.D.A impact requirements. A sunglass wearer may be put at risk if he wears sunglasses which have been made using only the front or back wafer of the laminate. It may be necessary for a prescription sunglass manufacturer to ensure that non-laminated wafers are not mounted in sunglass frames for general use. One way to achieve this end is to ensure that the lens wafers are visibly identified with a warning symbol as unsuitable for use, in such a way that after the wafers are laminated, the warning is no longer visible. For example, the current Matrix® lens lamination system includes a warning symbol in the centre of the contact surface of each lens wafer - a roughened area of the surface that causes unacceptable disturbance of the wearer's vision and thus

effectively prevents use of non-laminated wafers alone in spectacles. However, when the wafers are laminated using an adhesive of refractive index suitably matched to the lens material, the interface corresponding to the roughened surfaces optically disappears, so that the warning symbol is no longer visible.

If the light absorbing coating is applied over such a roughened contact surface, it is visible from the front of the wafer. It is also visible from the back of the wafer, because until the wafer is laminated, it is exposed to air rather than another lens wafer, so the coating does not perform antireflectively as designed. The roughened surface causes substantial light scattering toward the wearer and significantly disturbs his vision, so much so that the front lens wafer would not conceivably be used in a non-laminated state as a sunglass lens. After lamination, the coating is antireflective when viewed from the rear - light scattering from the roughened surface is very weak and so the roughened area is invisible to the wearer. If the contact surface of the lens wafer is roughened in a cosmetically pleasing fashion, then not only are non laminated lens wafers clearly identified, but after the coated wafers are laminated, a logo that is visible from the front of the lens but yet does not disturb the wearer's vision results.

Accordingly, in a preferred embodiment of the present invention a contact surface of the front and/or back lens wafer bears a mark thereon, the mark being substantially visible from both sides of the wafer before lamination, but which becomes substantially invisible from the eye side of the finished laminate lens. Preferably the mark on the contact surface is visible from the front of the laminated lens.

In an alternative embodiment where the mark on the contact surface is not visible from the front of the final laminated lens, the light absorbing coating includes a silica top layer, the silica top layer bearing a mark visible prior to lamination, as discussed above.

Preferably the visible mark is rendered substantially invisible when the lens wafer is contacted with a laminate adhesive having a refractive index approximately equal to that of the silica layer.

The light absorbing coating may for example be purposefully constructed to have a top layer of silica, which has a refractive index of approximately n=1.47. An excimer laser or other etching technique can be applied to remove (or merely reduce the thickness of) the top silica layer of part of the coating in the form of a warning label, which will be very visible before the wafer is laminated. However, after lamination, glue will fill the depressions caused by the etching, and because the glue can be chosen to have a refractive index very close to that of silica, the etched markings will have no optical effect and hence disappear, making the laminated lens suitable for use.

Alternatively, instead of removing part of the top silica layer, a warning label may be deposited on top of the silica layer with a suitably index-matched material, for example an adhesive or polymer material. Again, after lamination, glue will fill the void around the raised warning label, and because the glue can be chosen to have a refractive index very close to that of silica and the label itself, the warning marking will have no optical effect and hence disappear, making the laminated lens suitable for use.

Further characteristics and advantages of the present invention will be apparent from the following description of drawings and examples of embodiments of the present invention, given as indicative but not restrictive.

In the figures:

Figure 1 illustrates an embodiment of a sunglass lens according to the present invention with the light absorbing coating inside the laminate.

Figure 2 illustrates the attenuation of transmitted light through the sunglass lens of Figure 1 from a forward light source.

Figure 3 illustrates the attenuation of reflected light from the sunglass lens of Figure 1 from side glare.

Figure 4 illustrates the transmission spectra of a "black" laminated lens

(see Table 1), as compared to a typical liquid-dye tinted hard resin sunglass lens.

Figure 5 illustrates an embodiment of a laminated sunglass lens with semi-visible internal markings.

Figure 6 illustrates an embodiment of a sunglass lens according to the present invention with the light absorbing coating on the outside surface of the front wafer.

Figure 7 illustrates the attenuation of transmitted light through the sunglass lens of Figure 6 from a forward light source.

Figure 8 illustrates the attenuation of reflected light from the sunglass lens of Figure 6 from side glare.

Figure 9 illustrates an embodiment of a sunglass lens according to the present invention with the light absorbing coating on the outside surface of the back wafer.

Figure 10 illustrates the attenuation of transmitted light through the sunglass lens of Figure 9 from a forward light source.

Figure 11 illustrates the attenuation of reflected light from the sunglass lens of Figure 8 from side glare.

EXAMPLE 1

Light absorbing coating on the inside of a laminated lens

Figure 1 shows a preferred embodiment of a tinted optical lens according to the present invention. The front and back lens wafers are hard resin plastic wafers from a commercial ophthalmic lens system (Sola International Matrix® system). The back lens wafer is supplied with its external surface pre-coated with a scratch resistant and anti-reflective coating. The external surface of the front

wafer is also treated with a scratch resistant coating. The internal surfaces of both wafers are of uncoated hard resin.

A light absorbing coating with asymmetric reflectance is applied to the interface surface of the front wafer. (It may equally well be applied to the internal surface of the back wafer instead. Only the first case will be discussed for simplicity.) The coating is designed so that when the wafers are laminated, neutral attenuation of transmitted light, an aesthetically pleasing colour when viewed from the front of the lens and anti-reflection from the wearer-side of the lens result, as shown in Figures 2 and 3. Referring to Figure 3, it will be appreciated that possible reflections from surfaces behind the light absorbing coating do not contribute in any significant manner, because their intensity is severely reduced by the incident light having initially passed through the light absorbing coating. Such reflections are therefore not indicated in the figure.

The multi-layer light absorbing coatings consist of layers of absorbing materials and generally transparent dielectrics. The layers of absorbing material provide the attenuation of transmitted light. The degree of attenuation is controlled by adjusting the total thickness of these layers. If the absorbing material has a neutral transmission spectrum (as do many metals), the transmission of the coating will also be neutral, which is highly desirable for a sunglass lens that does not distort colour vision. By appropriately selecting the thicknesses of the various layers (which today is commonly achieved with the aid of computer software packages), the reflectance of the coating may be designed to have the required properties of a pleasing colour when viewed from the front of the lens and anti-reflection from the wearer side.

Table 1 lists the materials and layer thicknesses used in three differently coloured embodiments of the light absorbing coating. The coatings were deposited using a commercial evaporative box coater (Satis 1200).

TABLE 1

Layers			Thickness (nm)		
Number	Material	Primary function	Bronze	Blue	Black
Substrate					
1	Cr	Adhesion to substrate	0.5	0.5	0.5
2	TiO_2	Front colour	37	35	20
3	SiO_2	Front colour	9	50	20
4	TiO_2	Front colour	88	-	20
5	Cr	Absorption	14	12	12
6	SiO_2	Back AR	65	65	65
7	Cr	Absorption	9	9	9
8	SiO_2	Back AR	85	85	85
9	Cr	Absorption	2.5	2.5	2.5
10	SiO_2	Scratch resistance	5	5	5

Table 1. Composition of three differently coloured embodiments of the light absorbing coating as deposited inside the laminated sunglass lens.

The sequence of layers is relative to a light ray entering the front surface of the optical lens.

Table 2 shows the optical performance of the sunglass lenses in transmittance.

TABLE 2

Transmission	Bronze	Blue	Black
Luminous transmittance (%)	12.1	11.4	13.5
CIE x coordinate (illum. C)	0.36	0.38	0.37
CIE y coordinate (illum. C)	0.35	0.37	0.35
Av. UVB transmittance (%)	0	0	0
Av. UVA transmittance (%)	1.8	1.4	2.2
Red traffic signal trans. (%)	16.3	16.3	18.1
Yellow traffic signal trans. (%)	13.6	13.3	15.3
Green traffic signal trans. (%)	11.1	10.1	12.3
ANSI Standard Z80.3 - 1997	yes	yes	yes

Table 2. Optical performance of the sunglass lenses in transmission.

As shown in Figure 4, where the transmission spectrum of the black-coloured sunglass lens is compared to a hard resin sunglass lens tinted by the traditional liquid dye tinting process, the light absorbing coating has a quite neutral, slightly brown transmission, which provides excellent colour vision.

Table 3 shows the reflectance characteristics of the laminated sunglass lenses. As seen from the wearer-side reflectances, the sunglass lenses are indeed quite anti-reflective of side glare.

TABLE 3

Sunglass lens reflectance	Bronze	Blue	Black
Front side			
Luminous reflectance (%)	8.6	15.8	4.5
CIE coordinate (illuminant C), x	0.36	0.23	0.26
CIE coordinate (illuminant C), y	0.35	0.23	0.24
Wearer side			
Luminous reflectance (%)	0.9	1.0	1.1
CIE coordinate (illuminant C), x	0.30	0.25	0.26
CIE coordinate (illuminant C), y	0.31	0.24	0.29

Table 3. Optical performance of the sunglass lenses in reflection.

EXAMPLE 2

In the embodiment of the present invention illustrated in Example 1 (with the light absorbing coating inside the laminate), it is possible to produce semi-visible markings or logos on the sunglass lenses, as shown in Figure 5. By artificially roughening the surface of the wafer on the interface surface underneath the light absorbing coating (for example by etching the mould from which the internal surface of the front wafer is cast in this case), patterns are created and embedded inside the lens after lamination. The roughened surface is visible from the front of the sunglass lens, because from this side of the light absorbing coating, the reflectance is non-negligible, so light is scattered from the roughened surface. From the wearer side, because the coating is anti-reflective, reflections from the roughened surface are extremely weak, so that the markings are almost impossible to see. Therefore the logo can even be placed in the optical centre of the lens without disturbing the wearer's vision.

EXAMPLE 3

Light absorbing coating on the outside surface of the front wafer of a laminated lens

Figure 6 shows another preferred embodiment of the sunglass lens. Again, the front and back lens wafers are hard resin plastic wafers from a commercial ophthalmic lens system (Sola International Matrix® system). The back wafer is supplied with its external surface pre-coated with a scratch resistant and anti-reflective coating. The external surface of the front wafer is also treated with a scratch resistant coating. The internal surfaces of both wafers are of uncoated hard resin.

In this embodiment, the light absorbing coating with asymmetric reflectance is applied to the outside surface of the front wafer. Neutral grey attenuation of transmitted light, an aesthetically pleasing colour when viewed from the front of the lens and anti-reflection from the wearer-side of the lens again result after the wafers are laminated, as shown in Figures 7 and 8.

Table 4 lists the materials and approximate layer thicknesses used in four differently coloured embodiments of the light absorbing coating. The coatings in this case were deposited using a thin film sputter deposition system.

TABLE 4

Layers			Thickness (nm)			
Number	Material	Primary function	Silver	Gold	Blue	Copper
Substrate						
1	SiO_2	Scratch resistance	50	50	50	50
2	Nb	Absorption	2	2	2	2
3	SiO_2	Back AR	80	80	80	80
4	Nb	Absorption	4	4	4	4
5	SiO_2	Back AR	80	80	65	65
6	Nb	Absorption	4	4	4	4
7	SiO_2	Back AR	40	40	20	40
8	Nb	Absorption	4	4	4	4
9	SiO_2	Back AR, front colour		10	40	10
10	Nb_2O_5	Front colour		10	30	30
11	SiO_2	Front colour	25	30	30	60

Table 4. Composition of four differently coloured embodiments of the light absorbing coating as deposited on the outside surface of the front lens wafer.

Table 5 shows the optical performance of the sunglass lenses in transmittance.

TABLE 5

Transmission	Silver	Gold	Blue	Copper
Luminous transmittance (%)	13.2	15.8	17.6	21.8
CIE x coordinate (illum. C)	0.33	0.33	0.36	0.33
CIE y coordinate (illum. C)	0.33	0.33	0.36	0.34
Av. UVB transmittance (%)	0.0	0.0	1.0	0.3
Av. UVA transmittance (%)	1.3	1.3	2.2	4.8
Red traffic signal trans. (%)	15.2	18.0	22.3	24.8
Yellow traffic signal trans. (%)	14.0	16.6	19.5	23.0
Green traffic signal trans. (%)	12.7	15.3	16.3	21.1
ANSI Standard Z80.3 - 1997	yes	yes	yes	yes

Table 5. Optical performance of the sunglass lenses in transmission.

Table 6 shows the reflectance characteristics of the laminated sunglass lenses. As seen from the wearer-side reflectances, the sunglass lenses are indeed quite anti-reflective of side glare.

TABLE 6

Sunglass lens reflectance	Silver	Gold	Blue	Copper
Front side				
Luminous reflectance (%)	15.4	11.0	17.8	5.6
CIE coordinate (illuminant C), x	0.32	0.35	0.23	0.35
CIE coordinate (illuminant C), y	0.33	0.37	0.23	0.34
Wearer side				
Luminous reflectance (%)	0.98	1.3	1.2	1.8
CIE coordinate (illuminant C), x	0.22	0.23	0.22	0.24
CIE coordinate (illuminant C), y	0.20	0.21	0.25	0.22

Table 6. Optical performance of the sunglass lenses in reflection.

EXAMPLE 4

Light absorbing coating on the outside surface of the front wafer of a laminated lens

Example 3 was repeated but utilising zirconium in place of niobium metal. Again a neutral grey transmission was obtained.

Table 7 lists the materials and approximate layer thicknesses used in silver and blue coloured embodiments of the light absorbing coating. The coating in this case was deposited using a thin film sputter deposition system. Tables 8 and 9 list the corresponding transmittance and reflectance performance.

TABLE 7

Layers			Thickness (nm)	
Number	Material	Primary function	Silver 2	Blue 2
Substrate				
1	SiO_2	Scratch resistance	50	50
2	Zr	Absorption	14.2	14
3	SiO_2	Back AR	66	63.1
4	Zr	Absorption	13.1	
5	SiO_2	Back AR	30.3	
6	Zr	Absorption	28.3	35.9
7	SiO_2	Back AR, front colour	10	128

TABLE 8

Transmission	Silver2	Blue2
Luminous transmittance (%)	12.6	13.6
CIE x coordinate (illum. C)	0.32	0.34
CIE y coordinate (illum. C)	0.32	0.33
Av. UVB transmittance (%)	0.0	0.0
Av. UVA transmittance (%)	2.4	3.0
Red traffic signal trans. (%)	13.6	16.2
Yellow traffic signal trans. (%)	12.9	14.3
Green traffic signal trans. (%)	12.4	12.6
ANSI Standard Z80.3 - 1997	yes	yes

TABLE 9

Sunglass lens reflectance	Silver2	Blue2
Front side		
Luminous reflectance (%)	28.0	25.8
CIE coordinate (illuminant C), x	0.32	0.27
CIE coordinate (illuminant C), y	0.33	0.29
Wearer side		
Luminous reflectance (%)	6.5	2.8
CIE coordinate (illuminant C), x	0.27	0.20
CIE coordinate (illuminant C), y	0.31	0.19

EXAMPLE 5

Light absorbing coating on the outside surface of the back wafer of a laminated lens

In the embodiment the light absorbing coating is deposited on the outside

surface of the back wafer as in Figure 9. In this embodiment of the present invention, no additional anti-reflective coating is required to minimise all back reflections to the eye of the wearer, as seen in Figure 11. It will be appreciated that possible reflections from surfaces behind the light absorbing coating do not contribute in any significant manner, because their intensity is severely reduced by the incident light having initially passed through the light absorbing coating. Such reflections are therefore not indicated in the figure.

It will be understood that the invention disclosed and defined in this specification extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

It will also be understood that the term “comprises” (or its grammatical variants) as used in this specification is equivalent to the term “includes” and should not be taken as excluding the presence of other elements or features.

SOLA INTERNATIONAL HOLDINGS LTD
By their Registered Patent Attorneys
Freehills Patent Attorneys 3 March 1999

FIGURE 1

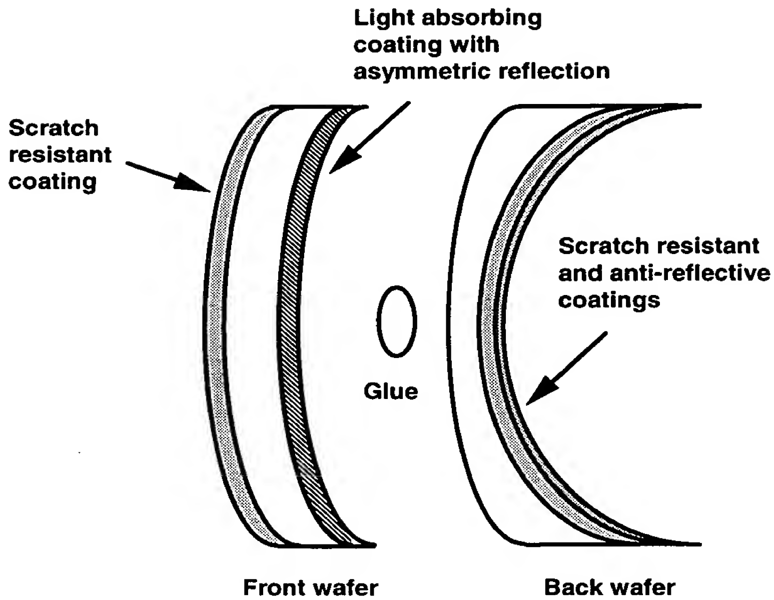
Light absorbing
coating with
asymmetric reflection
Scratch
resistant
coating
Scratch resistant
and anti-reflective
coatings
Glue
Front wafer
Back wafer

FIGURE 2

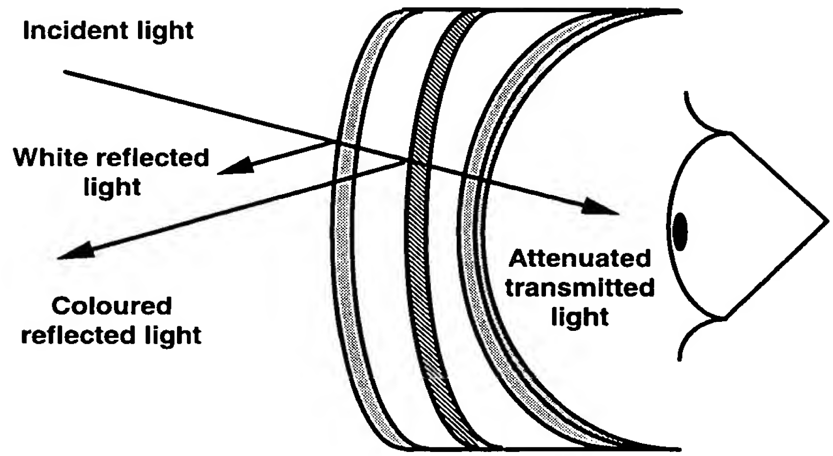
Incident light
White reflected light
Coloured reflected light
Attenuated transmitted light

FIGURE 3

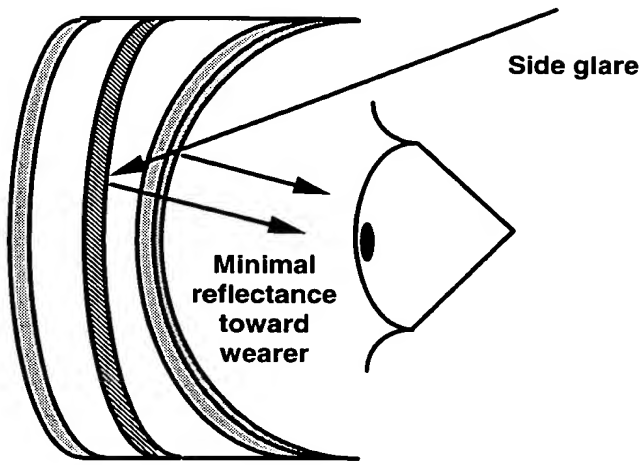

FIGURE 4

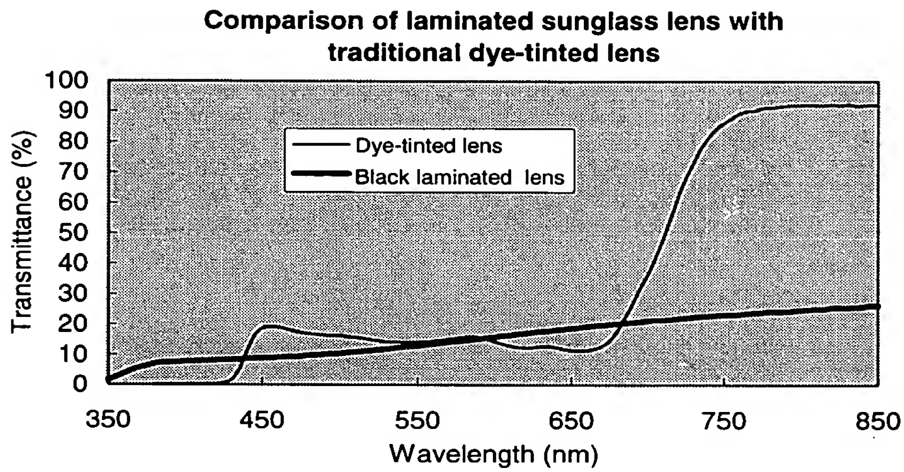
Comparison of laminated sunglass lens with traditional dye-tinted lens
Dye-tinted lens
Black laminated lens
Transmittance (%)
100
90
80
70
60
50
40
30
20
10
0
350
450
550
650
750
850
Wavelength (nm)

FIGURE 5

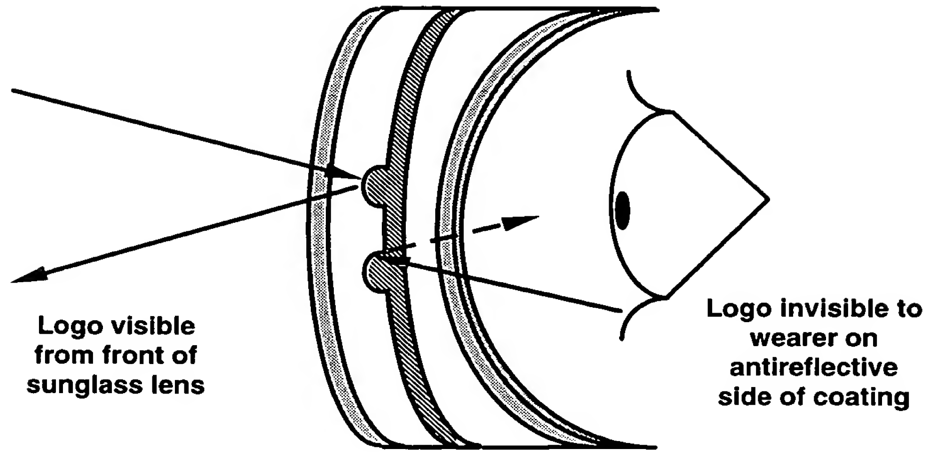
Logo visible
from front of
sunglass lens
Logo invisible to
wearer on
antireflective
side of coating

FIGURE 6

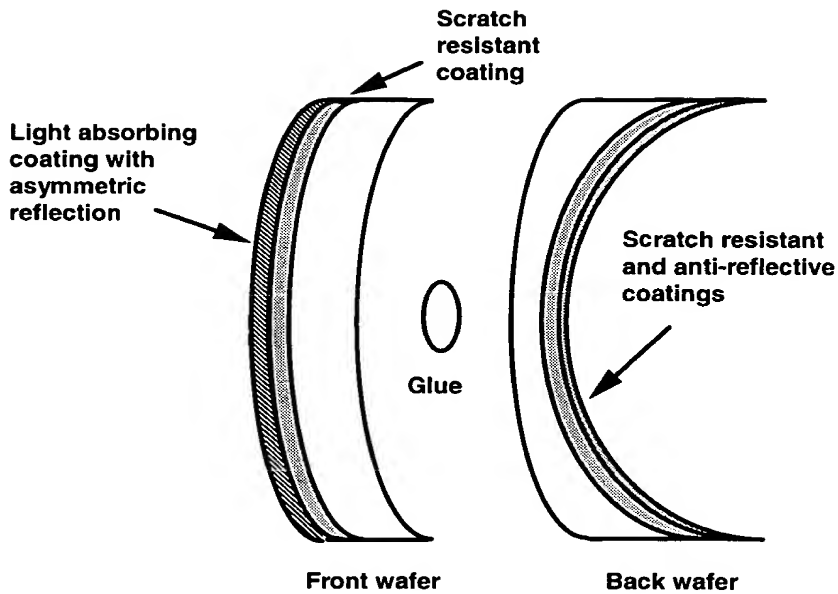
Scratch resistant coating
Light absorbing coating with asymmetric reflection
Scratch resistant and anti-reflective coatings
Glue
Front wafer
Back wafer

FIGURE 7

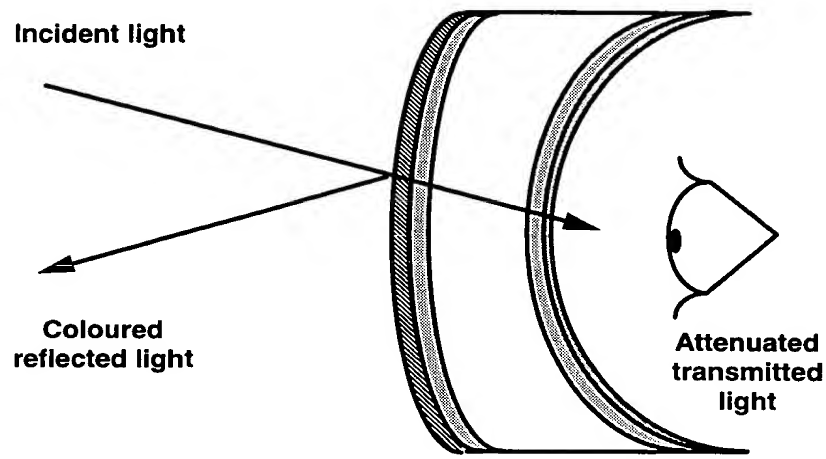
Incident light
Coloured reflected light
Attenuated transmitted light

FIGURE 8

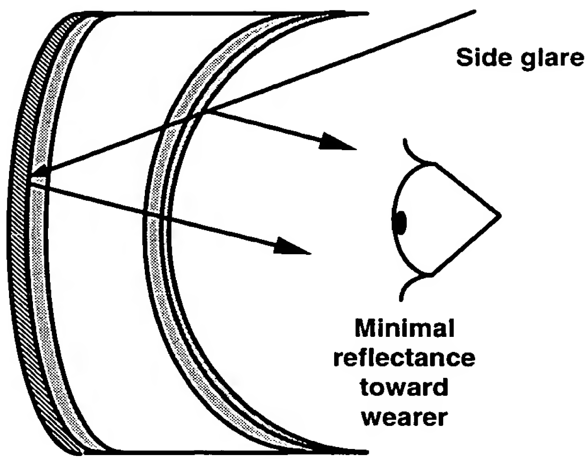

FIGURE 9

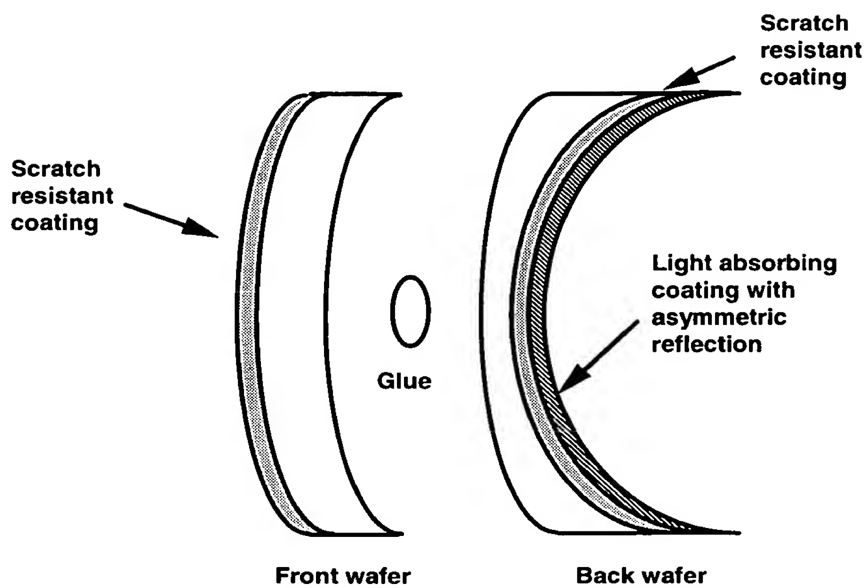
Scratch resistant coating
Scratch resistant coating
Light absorbing coating with asymmetric reflection
Glue
Front wafer
Back wafer

FIGURE 10

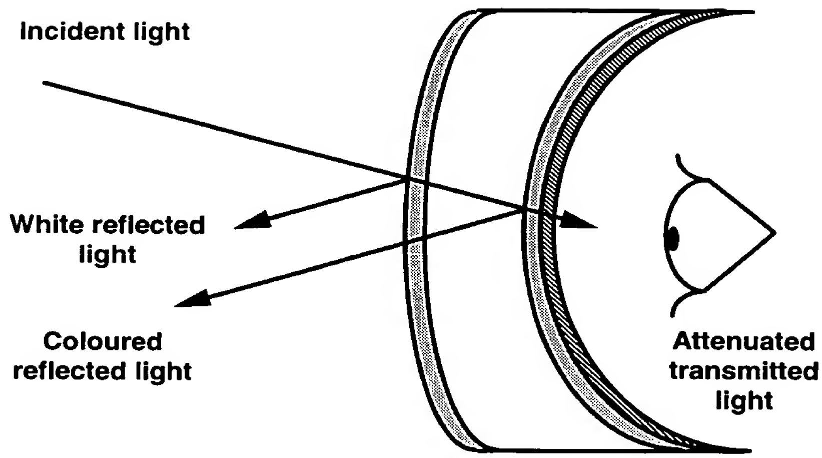
Incident light
White reflected light
Coloured reflected light
Attenuated transmitted light

FIGURE 11